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Elasticity and Rheology of Platinum Under High Pressure and Nonhydrostatic Stress

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Beamline: X17C

Introduction: Understanding how a material behaves at its elastic limit provides fundamental insight into the physics of solid structure, atomic bonding, and defect microdynamics. Platinum is an important high pressure material standard owing to its chemical inertness and the high-pressure high-temperature stability of its face-center-cubic structure. In addition to its value as a materials standard, platinum's ability to absorb infrared radiation makes it a commonly used internal pressure standard in laser-heated diamond cell experiments designed to measure high pressure high temperature phase stability and equations of state. Here we investigate the plastic and elastic behavior of platinum subjected to large, non-hydrostatic stresses in the diamond cell using radial x-ray diffraction techniques[*1;2*].

Methods and Materials: Two samples of a thin foil of polycrystalline platinum were examined using radial x-ray diffraction, with the x-ray beam passing between two diamond faces and through the pt sample contained within a beryllium gasket. Each diffraction pattern was collected at a fixed 2θ angle for periods of time varying from 5 minutes to 5 hours. Most patterns were collected for ~10 minutes. At each compression of the diamond cell, a series of 5 to 12 diffraction patterns were obtained by changing the angle defined by the normal of the diffracting lattice planes and the principle stress axis (ψ) by rotating the diamond cell about the axis defined by the incoming x-ray beam, perpendicular to the maximum stress direction (the diamond cell loading axis).

Results: We determine the lower-bound of the yield strength of platinum to be 2 to 4 GPa in the pressure range of 5 to 20 GPa at room temperature, showing a higher strength than Au and Mo, but a slightly lower strength than Re [3,4]. The measured elastic anisotropy, $S = S_{11}-S_{12} -0.5S_{44}$, is 0.003 GPa^{-1}, in good agreement with ambient measurements, and approximately constant throughout this pressure range. Both the 111 and 200 lattice parameters were monitored at the maximum stress direction over the course of four hours showing a) a systematic increase with time of the lattice parameter of both the (111) and (200) lines and b) a trend toward convergence of the (111) and (200) diffraction lines. These observations signify a time-dependent relaxation of the nonhydrostatic stress, pointing towards the possibility of rheology measurements at high pressures within the diamond anvil cell. Side diffraction experiments may provide a sensitive method to examine the stress state of each separate material within a composite, allowing a test for theories of composites, and to examine the mechanical behavior of a micro-scaled composite materials. For example, the hydrostatic pressure determined from platinum is systematically lower than the pressure determined from a silicate spinel within the same sample chamber, by 0.8 to 5.5 GPa across the pressure range.

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